Chapter 1 Radiation and Radioactivity

1.1 X-rays and nuclear radiation

A Ionizing radiation

1 Radiation is the _____ emitted by a source that travels through a medium or a _____. It can be in the form of particles or _____.

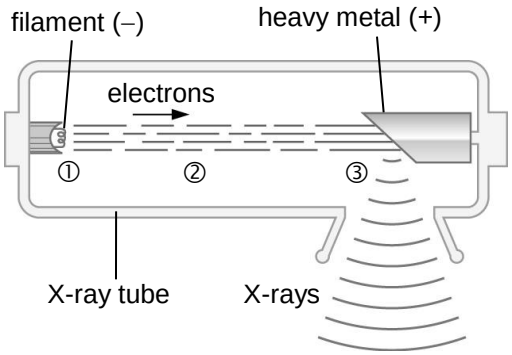
2 Radiation that has high enough energy to _____ molecules is called ionizing radiation, which can remove _____ from molecules and turn the molecules into _____. Examples include _____ and _____ radiation.

3 Ionizing radiation can damage _____ in our body.

Warning sign of ionizing radiation:

B X-rays

1 X-rays are produced when _____ electrons hit a heavy _____.

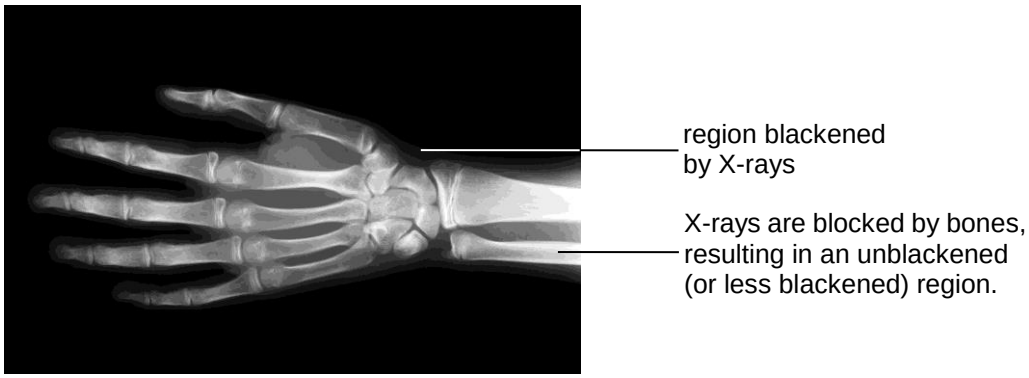


① _____ are emitted from the heated filament connected to the _____ terminal.

② The electrons are _____ by the high voltage.

③ Fast-moving electrons hit the heavy metal (connected to the _____ terminal) and produce _____.

2 X-rays can blacken a photographic film. Low-frequency (_____-energy) X-rays can penetrate flesh but not _____, and are used in medical imaging.



3 X-rays are also used for inspecting luggage at airports and inspecting cracks and faults in industry.

C Nuclear radiation

1 Nuclear radiation is the high-energy radiation emitted spontaneously by _____ substances. This phenomenon of radiation is called _____.

2 Similar to X-rays, nuclear radiation can _____ a photographic film.

3 Three common types of nuclear radiation and their properties:

	α radiation	**β radiation**	**γ radiation**
(a) Nature	streams of positively charged _____ _____	streams of negatively charged fast-moving _____	electromagnetic waves of very high frequency
(b) Relative charge		–1	
(c) Speed	a range of speeds: up to 0.1*c*	a range of speeds: up to 0.9*c*	a single speed: _____

* c = speed of light = 3.00×10^8 m s^{-1}

1.2 Radioactivity

A Background radiation

1 Background radiation is the _____ radiation present in the environment.

2 Sources of background radiation:

(a) Natural sources (~80%): cosmic rays from outer space, _____ gas from ground, building materials and soil, food and drinks

(b) Man-made sources (~20%): mainly due to _____ use of radiation

B Safety precautions

1 Safety precautions in handling radioactive sources:

(a) Store and transport all sources in a suitable _____ container. Lock them away when not in use.

(b) Handle the source with forceps or special lifting tools. Take great care not to drop the source.

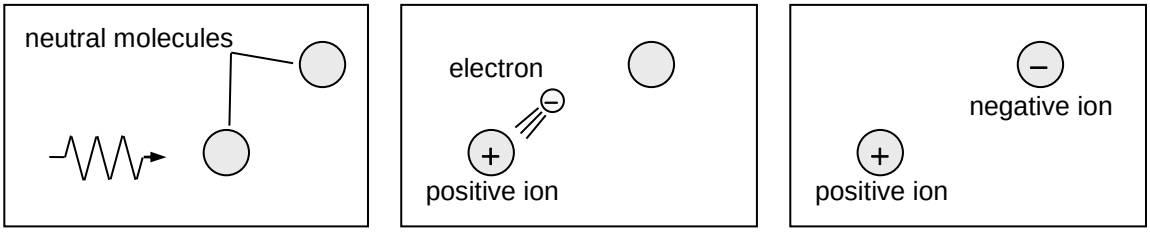
(c) Keep the source at arm's length, and point it away from the human body, especially the eyes.

(d) Carefully plan the experiments to _____ the time that the source is used.

(e) Label the storage place with _____.

C Ionizing power

1 When nuclear radiation passes through a gas, it removes _____ from some gas molecules. As a result, _____ are formed. The gas is said to be _____.



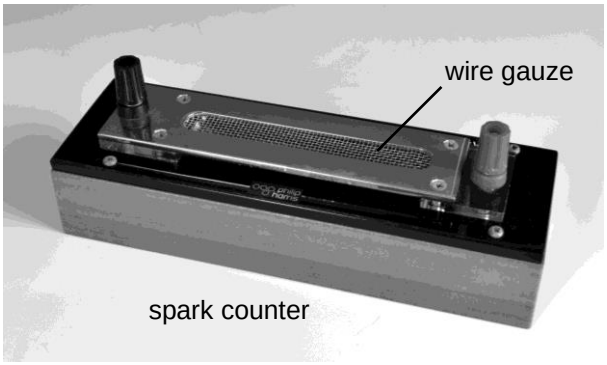
① Radiation strikes a neutral molecule.

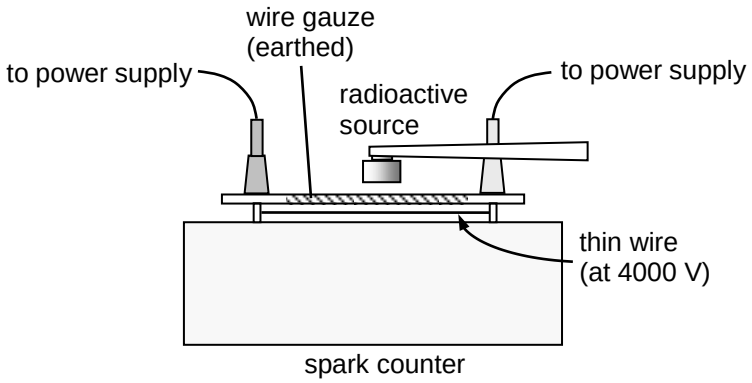
② An electron is struck out and the molecule becomes a positive ion.

③ The electron is captured by another molecule to form a negative ion.

2 The _____ of radiation describes the ability of ionizing a material.

3 A _____ can be used to study the ionizing power. When a radioactive source is held close to the wire gauze, _____ are produced. The stronger the ionizing power of the radiation, the _____ the sparks are produced.





4 When α, β and γ sources are held close to the wire gauze in a spark counter, the following results are obtained.

(a) α source: a lot of sparks

(b) β source: _____

(c) γ source: _____

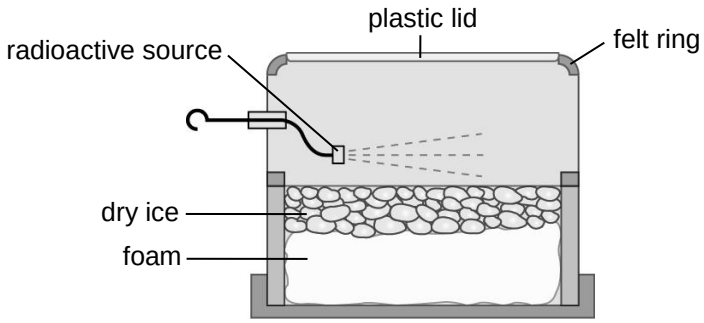
Ionizing power of the nuclear radiation:

_____ > _____ > _____

D Cloud chamber tracks

1 Nuclear radiation produces tracks of ions in a _____.

diffusion cloud chamber



2 The stronger the ionizing power of the radiation, the _____ the tracks are.

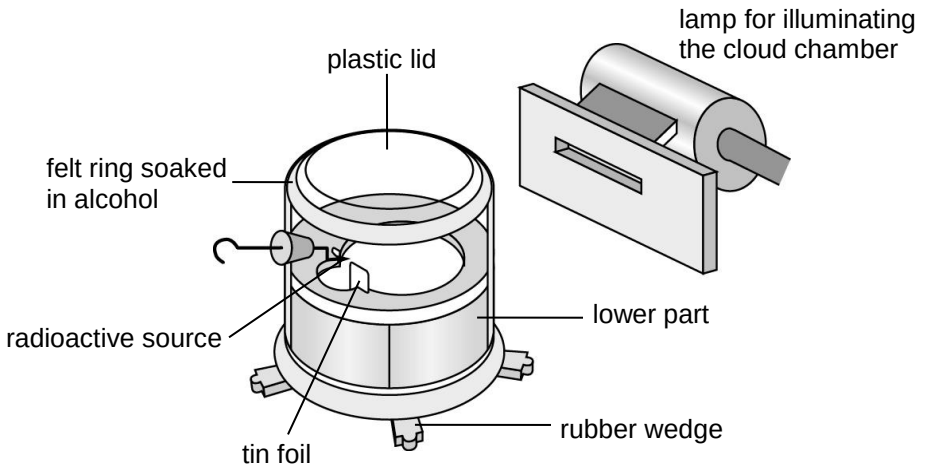
Experiment: Diffuse cloud chamber

① Put some _____ in the lower part of the cloud chamber.

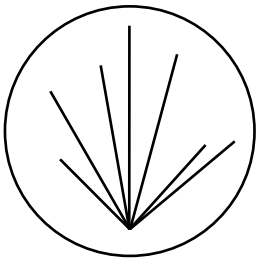
② Add some alcohol to the felt ring. Cover the chamber with the lid.

③ Level the chamber using rubber wedges and illuminate it with a lamp.

④ Insert a weak radioactive source and observe from above the tracks produced.

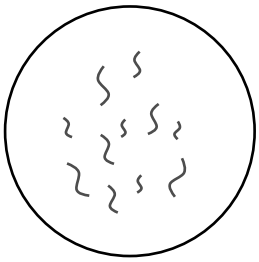


3 The following results are obtained from the experiment.



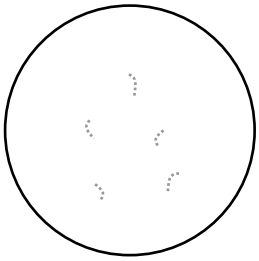
α source: tracks are _____ and _____

⇒ strong ionizing power



β source: tracks are _____ and _____

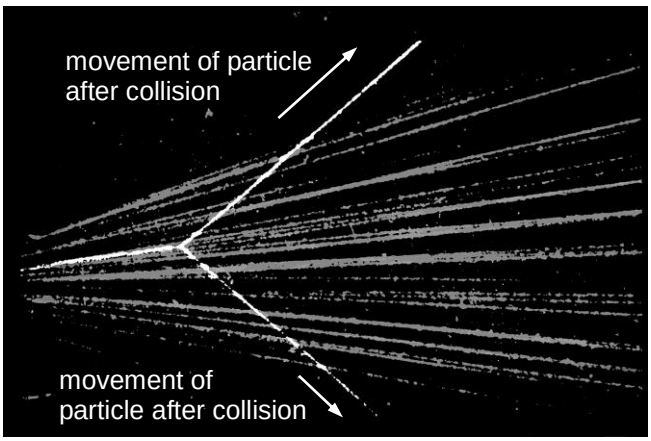
⇒ weak ionizing power



γ source: tracks are _____ and _____ seen

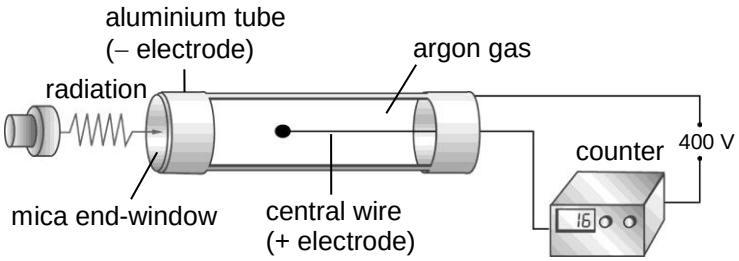
⇒ very weak ionizing power

4 Scientists inserted an α source in a cloud chamber filled with helium gas and observed the _____ tracks. As such tracks are formed only if the two colliding particles have the same mass, scientists deduced that α radiation is a stream of _____.

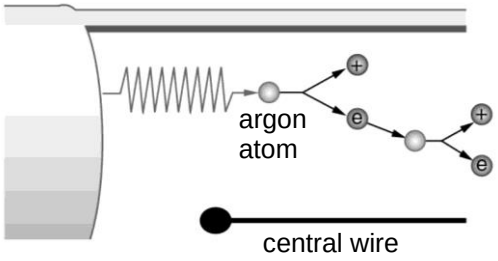


E Geiger-Müller tube (G-M tube)

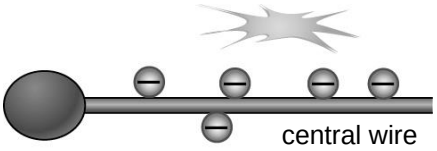
1 A G-M tube connected to a _____ can measure the count rate of the radiation.



① The G-M tube is filled with argon gas at low pressure. A high voltage is applied to the central wire.



② When radiation enters the tube, it ionizes the argon atoms.



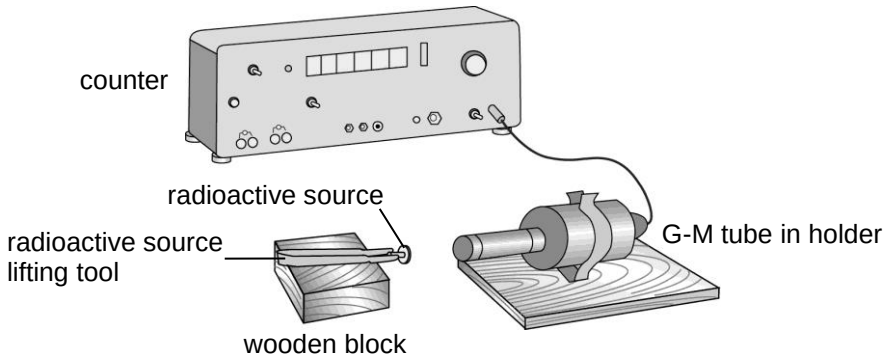
③ When electrons are attracted to the central wire, a voltage pulse is produced. The counter measures the number of voltage pulse detected. The number of counts per unit time gives the count rate.

2 _____ radiation enters a G-M tube all the time. In order to obtain the count rate solely due to a radioactive source, a correction should be made as follows:

Corrected count rate = measured count rate – _____

F Range and penetrating power

Experiment: Range and penetrating power of radiation



① Record the background count rate *B* with a G-M counter.

② Hold an α source about 1 cm from the G-M tube and take the count rate.

③ Insert sheets of paper as absorber between the G-M tube and the source. Record the number of sheets of paper that completely stops the α radiation (count rate drops back to _____).

④ Remove all the paper. Slowly move the source away from the G-M tube until the count rate drops to *B*. Measure the distance between the source and the G-M tube to obtain the _____ of α radiation in air.

⑤ Repeat the experiment using a β source and a γ source in turn (placed 5 cm from the G-M tube), and use aluminium sheets and lead sheets as absorbers.

1 From the experiment result,

range of the nuclear radiation in air:

_____ (over 100 m) > _____ (several metres) > _____ (a few centimeters)

2 (a) α radiation is stopped by 1–2 sheets of _____;

(b) β radiation is stopped by 5 mm of _____;

(c) γ radiation is never fully stopped but 25 mm of _____ halves its strength.

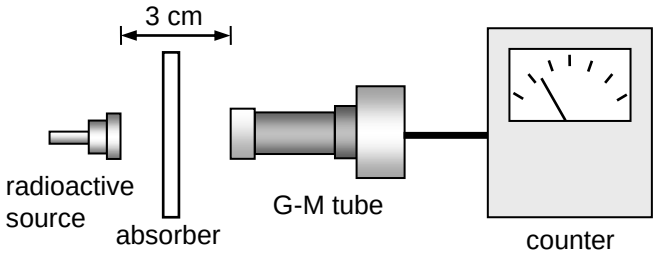
Penetrating power of the nuclear radiation:

_____ > _____ > _____

3 Radiation with a strong ionizing power has a _____ range in a material because the radiation quickly gives all its _____ to ionize molecules over a short distance.

Checkpoint 1

Different absorbers are put between a radioactive source and a G-M tube. The count rates measured for different absorbers are given in the following table. For each absorber, three readings are taken at 1-min intervals.



Absorber	Reading / counts per min		
	1st	2nd	3rd
Air	463	457	445
Paper	440	448	453
Aluminium plate (5 mm thick)	45	56	39
Lead block (25 mm thick)	42	49	38

(a) Different readings are obtained for the same absorber. What can you conclude from this?

(b) Which type(s) of radiation does the radioactive source emit? Explain your answer.

Solution

(a) Radiation from a radioactive source is emitted at a _____ (constant / slightly fluctuated) rate.

(b) The source emits _____ only.

No matter whether paper is inserted or not, the count rates are _____.

This shows that _____ radiation _____ (is / is not) emitted by the source.

When paper is replaced with the _____, a significant decrease in count rate is observed. This shows that _____ radiation _____ (is / is not) emitted by the source.

When aluminium is replaced with the _____, there is no significant decrease in count rate. This shows that _____ radiation _____ (is / is not) emitted by the source.

G Deflections in an electric field and a magnetic field

1 When a radiation enters an electric field or a magnetic field, it may be deflected. The direction of deflection depends on the _____ of the radiation.

(a) In an electric field,

(i) α radiation (_____ charged) is deflected to the _____ (same / opposite) direction of the electric field.

(ii) β radiation (_____ charged) is deflected to the _____ (same / opposite) direction of the electric field,

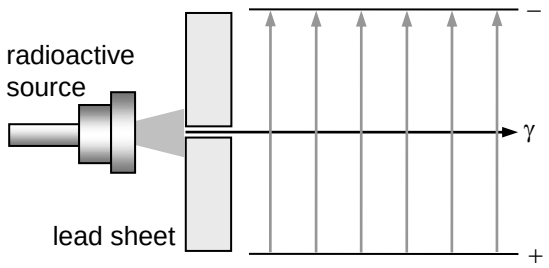
(iii) γ radiation (no charge) is not deflected.

(b) In a magnetic field, the direction of deflection can be determined by applying _____.

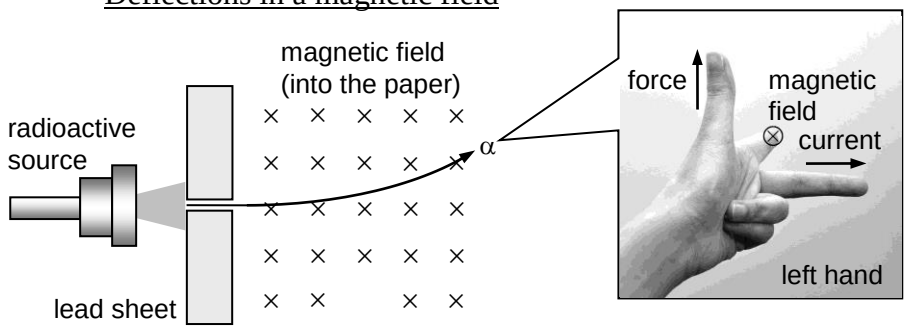
2 The extent of deflection in electric / magnetic fields mainly depends on the _____ of the radiation (its constituent particles). α particles are much _____ than β particles and therefore are deflected by a _____ extent.

3 Complete the paths of α, β and γ radiation in the electric field and the magnetic field shown below.

Deflections in an electric field



Deflections in a magnetic field



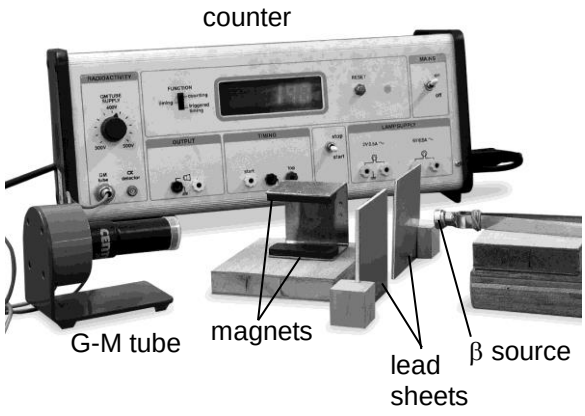
Experiment: Magnetic deflection of β radiation

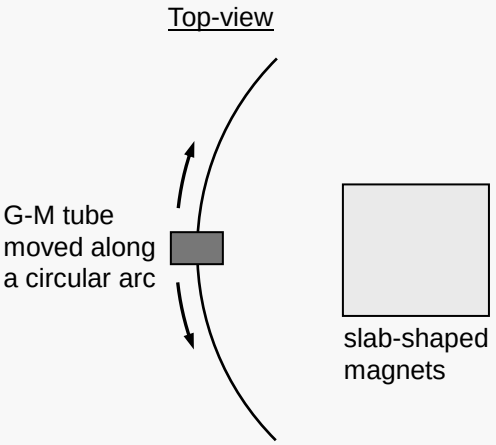
① Connect a G-M tube to a counter.

② Place a β source in front of the G-M tube. Form a narrow gap between the β source and the G-M tube using _____ blocks (or lead sheets). Make sure that the source, the gap and the G-M tube are aligned.

③ With no magnets in place, measure the count rate.

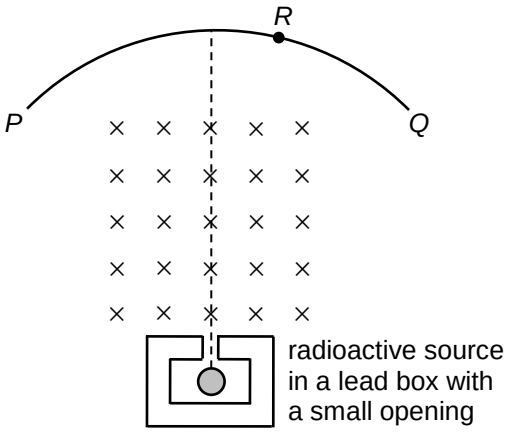
④ Put a pair of _____ in front of the gap so that the magnetic field points either upwards or downwards. Move the G-M tube along a circular arc. Locate a position on the arc where the _____ count rate is measured.





Checkpoint 2

A radioactive source is placed in front of a uniform magnetic field pointing into the paper. When a G-M tube is moved along arc *PQ*, the highest count rate is recorded at position *R*.



(a) What kind(s) of radiation is detected at *R*?

(b) A stronger magnetic field is then applied. What happens to the result? Explain brefly.

Solution

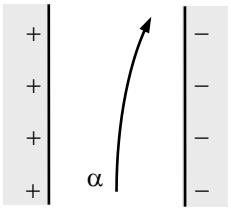
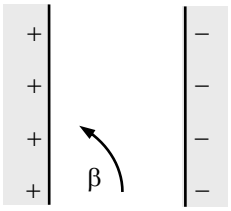
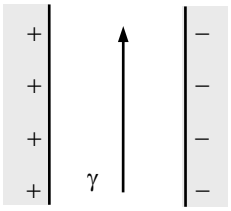
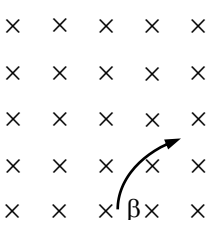
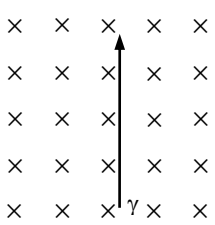
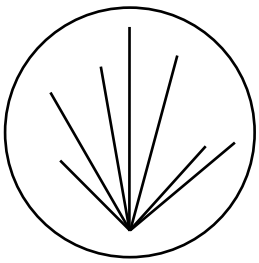
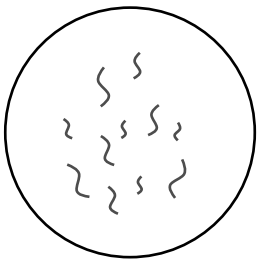
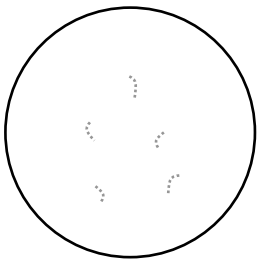
(a) _____ is detected.

(b) When a stronger magnetic field is applied, β radiation is deflected _____ _____ (more / less / by the same amount). As a result, the count rate at *R* is _____ and the position of the highest count rate moves _____ _____ *Q*.

6 Ω

2 Ω

H Comparison of α, β and γ radiation

	α radiation	β radiation	γ radiation
(a) Nature	streams of positively charged _____ nuclei	streams of negatively charged fast-moving _____	_____ waves (high frequency)
(b) Relative charge	+2 (for each particle)	–1 (for each particle)	no charge
(c) Speed	a range of speeds: up to 0.1*c*	a range of speeds: up to 0.9*c*	a single speed: *c*
(d) Ionizing power		weak	
(e) Penetrating power	low, stopped by 1–2 sheets of _____	high, stopped by _____	very high, never fully absorbed, halved by _____
(f) Range in air	several _____	several _____	over 100 m
(g) Deflection in electric field	very small 	large 	no deflection 
(h) Deflection in magnetic field	very small 	large 	no deflection 
(i) Cloud chamber track	thick and _____ 	thin and _____ 	scattered, hardly seen 
(j) Detectors	spark counter, ionization chamber, diffusion cloud chamber, G-M counter, photographic film	diffusion cloud chamber, G-M counter, photographic film	diffusion cloud chamber, G-M counter, photographic film